Shell Global Solutions

Holistic Considerations for Sustainable Remediation

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Concept of Sustainability

The Brundtland Commission famously defined sustainable development as…

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainability is the state where these conditions are met, most often assumed to require a balance of three components:

- **Protective and Protected Environment**
- **Vibrant Economy**
- **Supportive Quality of Life**

EPA – Green Remediation

Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites

http://cluin.org/greenremediation

- “The practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup action.”
- “The Agency has begun examining opportunities to integrate sustainable practices into the decision-making processes and implementation strategies…”
- “EPA recognizes that incorporation of sustainability principals can help increase the environmental, economic, and social benefits of cleanup.”

Measuring Sustainability

- CO_2
- water use
- occupational risk
- energy
- air impacts
- SO_X
- PM-10
- human exposure hours
- NO_X
- local issues
- treatment vs. containment
- land use
- recycled materials

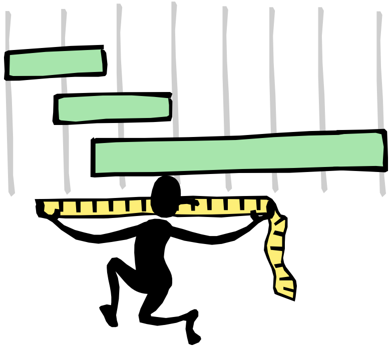
After: Deborah Goldblum, EPA Region 3

Considerations for Development of Sustainability Metrics

- What are the functional units of remediation?
  - Emissions (CO_2, GHG, water quality, etc.), safety (exposure duration on site, miles driven), resource consumption (energy, water), etc.
  - Time scale (site assessment and planning, system installation, O&M, closure)
  - Contributory Factors
    - Carbon footprint of material used in remediation (e.g. CO_2 footprint of the manufacturing of a steel GAC vessel used for site treatment)
- Factor Weighing and Analysis (site specific)?
  - CO_2, resources, safety, environmental cost

Integrating Sustainability into Cleanups

- Develop framework to assess sustainability
  - Factors (common language)
  - Measures



- Potential to use sustainability as a balancing criteria for cleanups

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RCRA Remedy Selection Criteria

Threshold Criteria

- Protect Human Health & the Environment
- Control Sources
- Meet Cleanup Objectives

Balancing Criteria

- Long-term reliability
- Reduction of toxicity, mobility or volume
- Short-term effectiveness
- Ease of implementation
- Cost
- Community acceptance
- State acceptance
- **Sustainability**

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Holistic Considerations

- Risk-Based
- Science-Based
- Environmental/Sustainability-Based

Risk-Based Remediation Paradigm

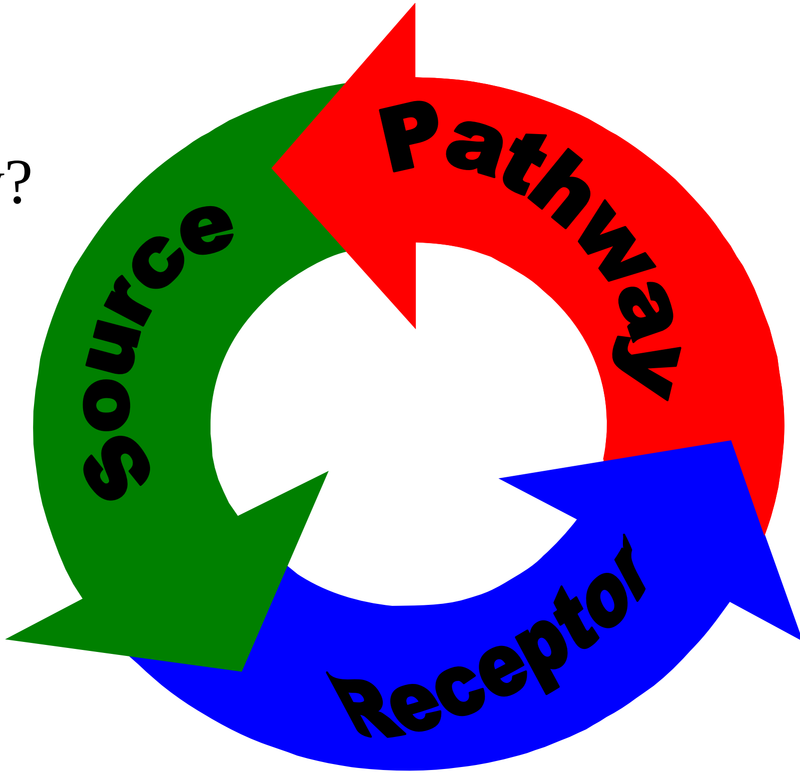
How can we break the complete pathway?

- remove the source

- reduce concentrations in the source

- eliminate or reduce exposure pathway

- remove the receptor

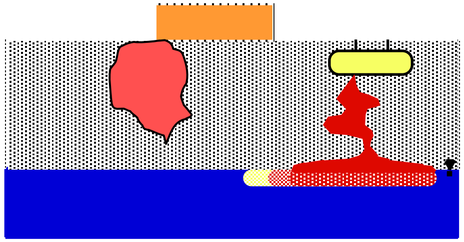


When is there a need for remedial action?

- Chemicals of concern (COC's) are above the appropriate target levels at the point of demonstration.
  - Which COC(s) are above target level(s)?
  - What pathway(s) is/are of concern?
  - What media is affected?

The Risk-Based Approach

Both the chemical properties and subsurface characteristics define the distribution and phases of chemicals in the subsurface.



Source Areas

- vapor phase
- unsaturated zone residual NAPL
- NAPL (mobile)
- *saturated zone residual NAPL (Smear Zone)*
- soluble groundwater plume

The Risk-Based Approach (Continued)

Considerations necessary to achieve remedial action goals

- All exposure pathways
- COC's
  - Chemical properties (chemical, physical, toxicological)
- Subsurface characteristics
- Distribution of COC's in the environment
- Chemical phases

The 4 NAPL risk pathways are:

- **Direct Contact**
- **Vapor Intrusion**
- **Groundwater**
- **NAPL Mobility**

Key questions for remediation

- Will active source area remediation reduce overall risk (all phases considered) to an acceptable level within a reasonable timeframe?
  - If remediation is not likely to reduce overall risk in a reasonable time, should this still be considered?
- Is containment (engineering control) an appropriate option?
  - Will containment protect the receptor?
  - Will source remediation reduce the containment lifetime to a reasonable level?
  - Is the source remediation technology likely to be successful and is it cost-effective relative to long-term containment?
- Are activity and use limitation controls appropriate with or without remediation?

The LNAPL Remediation Framework

- **Conduct initial LNAPL site assessment**
- **Develop LNAPL CSM**
- **Evaluate risk pathways for current and potential future risk**
- **If unacceptable risk exists, then address immediate risks**
- **Evaluate remediation potential**
- **Establish overall remediation goals for key pathways**
- **Develop measurable and quantifiable metrics related to the goals**
- **Evaluate technologies based on the metrics derived above for the 9 EPA criteria**
- **If one or more technologies can achieve the goal(s) utilizing the EPA criteria for the quantifiable metrics <u>(including sustainability),</u> then select most cost-effective alternative.**
- **If no technology can achieve the remediation goal(s) within a reasonable timeframe, then implement appropriate engineering and/or institutional controls.**

Safety Considerations in Remediation

Remedial Options?

- What remedial options can achieve the remedial action goal (metrics) for the pathway(s) of concern at the point of demonstration in a reasonable timeframe?

- Source Reduction
- Activity and Use Limitation Controls
    - Engineering Controls
    - Land Use Controls

Does mass reduction necessarily result in significant risk reduction?

- **Not Always**
  - With current technology, it may not be practicable to reduce residual NAPL in the saturated zone to a level which will result in acceptable soluble concentrations or mass flux.
  - Recent studies predict that > 80 - 95 % of the saturated zone residual NAPL must be removed to begin to affect the soluble plume within a reasonable timeframe (30-50 years).

Effect of Source Treatment on Remediation Timeframe (RTF)

FIRST ORDER EQUATION:

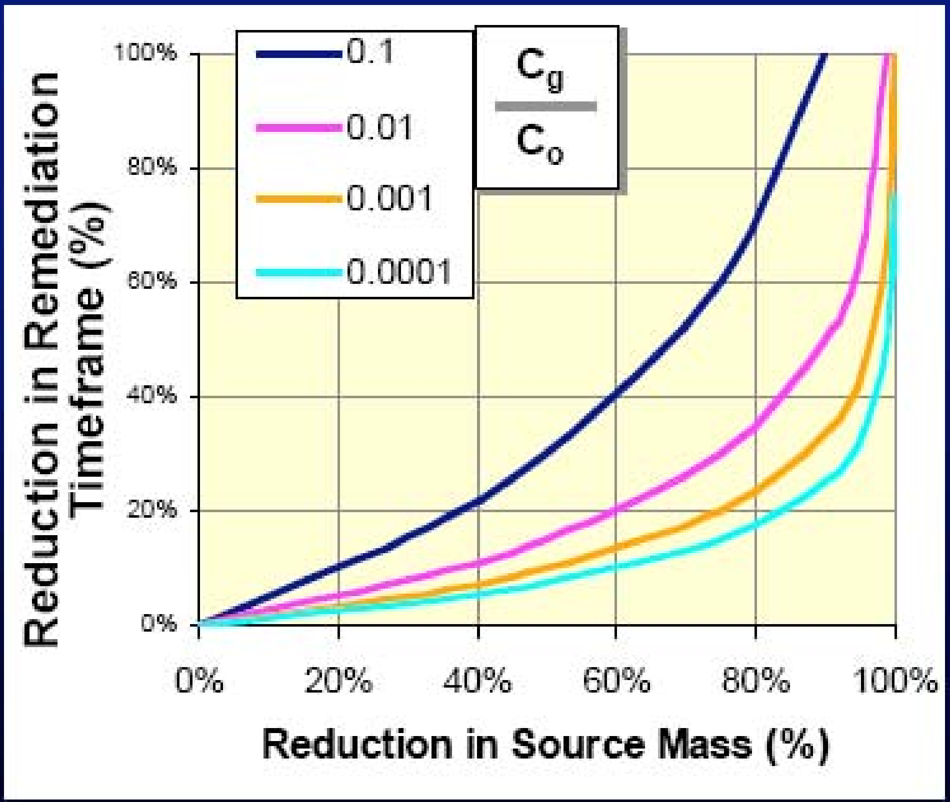
$$\frac{RTF_{SD}}{RTF_{MNA}} = \frac{\ln\left(\dfrac{C_g}{C_o\,RF}\right)}{\ln\left(\dfrac{C_g}{C_o}\right)}$$

C_g = GW Concentration Goal (such as MCL)

C_o = Original Source Conc.

RTF_{SD} = Remed. timeframe with *source treatment*

RTF_{MNA} = Remed. timeframe w/ *only natural attenuation* of source



After Newell, et. al. - 2006

Source Effects and Duration

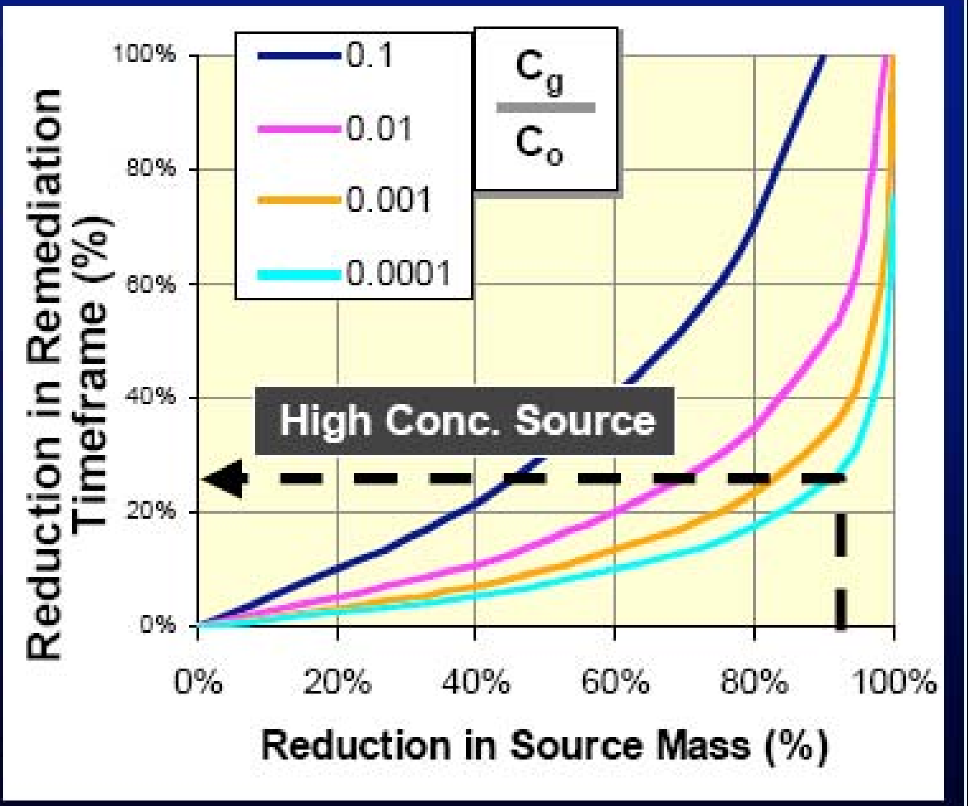
Effect of Source Treatment on Remediation Timeframe (RTF)

EFFECT OF PARTIAL SOURCE REMOVAL

- High-Conc. Source (Benzene = 50 mg/L)

90 % Source Removal =

25 % Reduction in RTF



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Source Effects and Duration

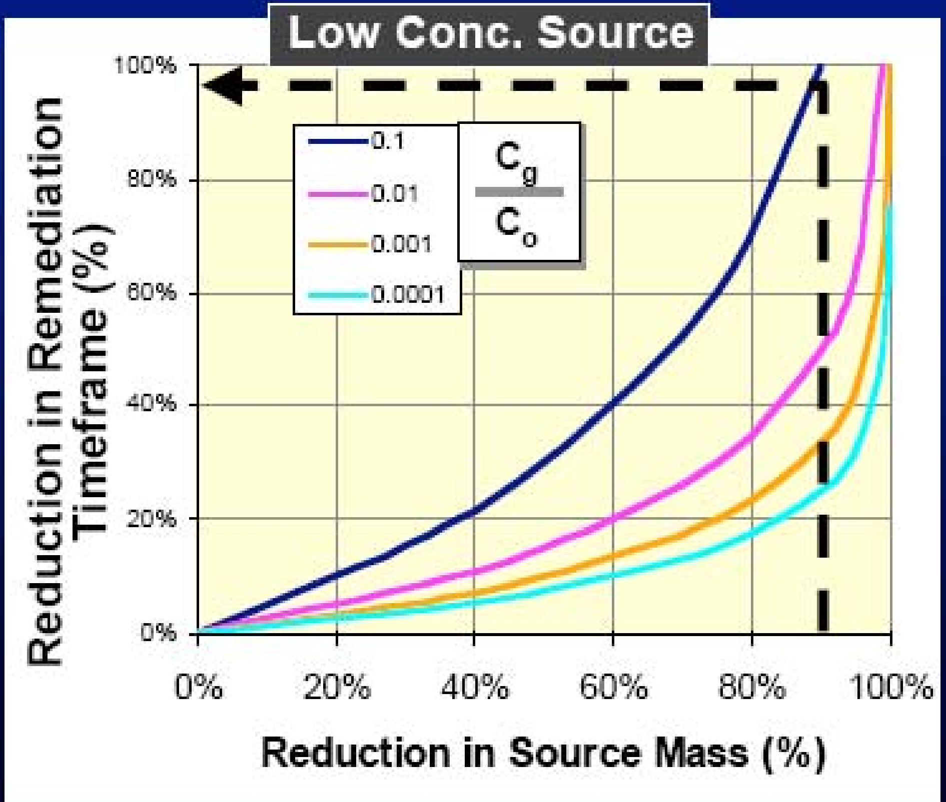
Effect of Source Treatment on Remediation Timeframe (RTF)

EFFECT OF PARTIAL SOURCE REMOVAL

- **Low-Conc. Source (Benzene = 0.05 mg/L)**

90 % Source Removal =

95 % Reduction in RTF



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Technology Limits

- Heterogeneity and access will control remediation effectiveness
- Hydraulic methods limited for NAPL source removal (especially with residual saturations of NAPL)
- Chemical cleanup methods limited to amenable components (e.g., volatile for SVE)
- Delivery of cleanup stream to NAPL-affected pore space is key to success of both methods
- The success hinges not on remedial design screening calculations, but on understanding the geologic & chemical distribution & relationship to cleanup operation

Common Themes in LNAPL Decision Initiatives

- Understanding of conditions and governing processes
  - I.E., Having a good NAPL CSM
- Recognizing technology limits within site-specific constraints
- Prioritization based on combination of threats & goals
  - Obviously, potential risk conditions are 1st priority
- **Develop attainable goals with quantitative metrics before implementation**
  - Location & timing are critical to metrics application
- Analysis of remedial feasibility, cost/benefit before implementation
  - So, need to have specific quantifiable goals first
- Site specific solutions, including engineered remediation or controls
  - Each site is different, no tailor-made solutions
  - Solutions must be effective, safe, constructible, and feasible
- This sets up metrics of achievable endpoints
  - Where, when, how, measured & revisiting vision of "success"

Sustainable Remediation

- SUstainable Remediation Forum (SURF)
  - Evaluation of holistic environmental/sustainability considerations in remediation decision making
  - Integrating sustainability principals, practices, and metrics into remediation projects
  - Multi-stakeholder, global initiative
  - Stakeholders include: agencies, industry, consulting, academia
- CA DTSC – The Green Remediation Team
- EPA Region 9 – Pilot Program
- EPA Green Cleanup Certification

Consideration of Risk, Science, and Environmental/Sustainability Factors

- Process to communicate issues to all stakeholders
  - ITRC NAPL Work Group
  - ASTM
  - SURF
  - ASTSWMO
- Implementing rational change
  - Integration with field staff (regulatory, industry, consulting)